15. *The* Archæan Geology *of* Anglesey. By C. Callaway, Esq., M.A., D.Sc., F.G.S. *With an* Appendix *on the* Microscopic Structure *of some* Anglesey Rocks, by Prof. T. G Bonney, M.A., F.R.S., Sec.G.S. (Read January 5, 1881.)

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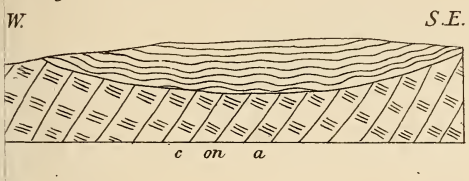


Fig. 5. Section in upper Quarry, Nebo.

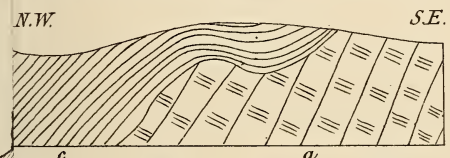
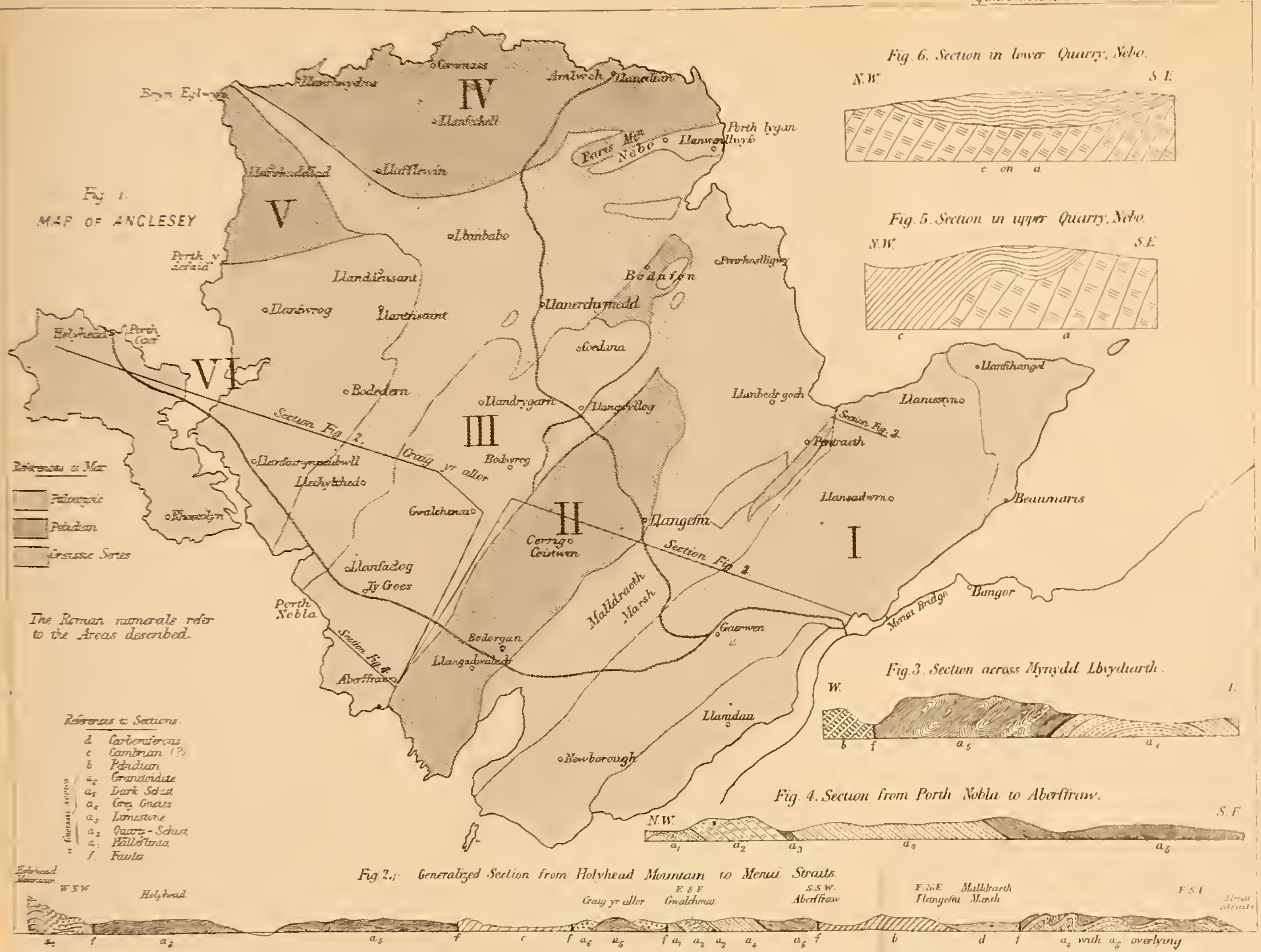




Fig. 3. Section across Myrydd Llwydiarth.



Fredk Dangerfield, Lith. London.

Introduction.

I have to submit evidence in support of the conclusion that there are represented in Anglesey two Precambrian or Archæan groups, each distinguished by well-marked lithological characters. They may be named respectively the Slaty and Gneissic formations. The "Pebidian" schists, as recognized by Dr. Hicks, I include in the gneiss group; but, in other parts of the island, I have worked out a great assemblage of fragmental felspathic rocks, which I believe to be of true Pebidian age. I shall also attempt to prove that the quartz rocks of Anglesey are included in the gneissic series. The microscopic notes, kindly furnished by Prof. Bonney, are based upon the specimens only, and have all the value of independent evidence. The growing importance of these ancient rocks would seem to require that the provisional term "Precambrian" should give place to a word which can be permanently used; and I have ventured to adopt the term "Archæan," so widely employed by Continental and American geologists. To the words "Azoic" and "Eozoic" there are obvious objections.

A. Description of Areas and Sections.

I. Menai Anticline.

For convenience I accept this name for the rocks lying between Menai Straits and the great fault which throws down the newer Palæozoic rocks of Malldraeth Marsh, though the term is not strictly applicable. It is true that the strata on the south-east side of the area dip to the south-east, and those on the north-west side to the north-west; but between these two extremities the undulations are frequent, and some of the dips are probably overthrows.

a. *Gneissic Series.*

Two Varieties of Gneiss.—The structure of the area is rendered much clearer by the recognition of two prevailing gneissic types—a dark micaceous or hornblendic variety, associated with chloritic schists*, and a greyish or light-red rock clearly foliated into an ordinary ternary gneiss. In the Craig-yr-allor anticline † the two varieties are also recognizable, the grey gneiss passing up through the dark type into the granitoidite. In the Menai district the dark schist holds the same relation to the grey variety, and the passage between the two may be seen at many points.

1. *Gneiss south of Pentraeth.*—Next to the fine section at Gaerwen ‡, the rocks south and east of Pentraeth require notice. The band coloured "greenstone," running from Tai hirion north-north-east to Plâs-gwyn lodge, appears to be a highly-altered hornblendic gneiss, with a north-west dip. In the field to the south-east of the lodge is a small quarry of typical grey gneiss; and in the plantation

* Throughout the paper the terms "schist" and "schistose" are strictly confined to foliated rock.

† Geol. Mag., March 1880, p. 119. ‡ Geol. Mag., March 1880, p. 121.

a few yards to the north-west we find the dark-green schist in its usual position above, both dipping to the north-west.

Following the strike to the north-east, the gneiss is seen to contain angular pieces of quartz, some of which are flattened in the foliation-planes, so as to appear like ordinary folia.

2. *Mynydd Llwydiarth.*—This elevated ridge, trending to the north-east for nearly a mile and a half, is composed of highly contorted gneiss. The general dip is north-west; but in some places the beds undulate to the south-east; and the thickness cannot be great. The rock is more quartzose than usual; and the quartz fragments become much more numerous,—the two facts suggesting the proximity of quartz land. The gneiss, rolling in frequent contortions, is finely exposed in low vertical cliffs; and the angular pieces of white quartz studding and projecting from the surface produce a very striking effect. Both types of gneiss appear to be present; but the felspar being less abundant, the rock is brought into closer resemblance to the micaceous and chloritic schists of Holyhead. On the north-western slope the gneiss is extensively brecciated, and the presence of a fault is further inferred from an abrupt transition to younger formations. At the foot of the slope, near the fault, the gneiss becomes somewhat granitoid, suggesting the commencement of the passage into granitoidite, which is seen so clearly in the Craig-yr-allor anticline. At the extreme north-east of the ridge, on Red Wharf Bay, the green schist is exposed for some distance across the strike to the east; but south of Wern we come onto the grey gneiss, all the dips being north-west. Further to the east, at Bryn y Castell, the grey type is again seen, but with the dip reversed; and at Hafodty, still further to the south-east, the dark schist comes in again. This is a clear anticline, the grey gneiss exposed at the apex throwing off green schist in opposite directions. The structure of this district is shown in Pl. VIII. fig. 3.

3. *Gaerwen to Menai Bridge.*—Crossing the anticline from Gaerwen, we find at the railway-junction that the dark schist has rolled over to the south-east; but half a mile to the south-east, near Llanddaniel, the series, represented by contorted quartzose chloritic schist, dips north-west. Exposures then are rare till we come to the Anglesey column, where dips are in opposite directions, but usually to the north-west. This rock is of the ordinary dark green type, occurring everywhere above the grey gneiss in both the Menai and Craig-yr-allor areas. It has been described by Prof. Bonney *. On the Straits, near the west end of Menai Bridge, green schists occur of the ordinary varieties.

From the above facts it is clear that the rocks of the anticline belong to the gneiss series. Well-foliated gneiss occurs at numerous localities; and the green schist is so intimately associated with it, as an upper band, as to remove all shadow of doubt that the two types form one unbroken group. In this area I have not found a trace of any thing but true crystalline schists.

The thickness of the group is not great. The foldings are nume-

* Quart. Journ. Geol. Soc. vol. xxxv. p. 308.

rous, the lower gneiss being brought up to the surface at many points. Probably the entire series is exposed west of Gaerwen, where the total thickness can hardly reach 1000 feet.

An isolated mass of schist occurs south-west of Pentraeth. It is about a mile long by half a mile broad, and is bounded by faults on all sides. Carboniferous Limestone surrounds it on three sides. On the east it is separated from the main mass by a faulted strip of the formation now to be described.

b. *Slaty Series.*

This wedge is composed of rocks of a newer Archæan group. At Tan y graig, south-west of Pentraeth, is a greenish, coarse, slaty variety. In the fields to the north-west, a jaspery rock projects in small knolls through the turf; but its relation to the bedded type is obscure. Crossing a hollow to the east, we come to a ridge, the western slope of which is occupied by massive breccias. The fragments and the matrix are similar, and are composed of a grey and purplish dolomite (Note 40, p. 235). Further to the north-east, above Wugan bach, is a light-purple slaty rock, which in places is literally smashed. Between this point and Plâs gwyn, along the ridge, the prevailing type is a purplish ashy rock, sometimes brecciated, and in places altered almost to a hornstone. The dip is high to the north-west. The breccias of this ridge are obviously connected with faulting. North of Plâs gwyn, on the same strike, is a puzzling rock, which, under the microscope (Note 41, p. 236) appears to be a limestone rendered impure by volcanic mud. Slaty beds are again seen to the north-east of Pentraeth, dipping south-east.

For the greater part of its length this mass is separated from the Menai anticline by a faulted strip of Palæozoic shale; but north-east of Rhiwlas it comes up against the gneiss, the fault between the two formations running along a hollow. The heavy breccias which fringe both groups point to excessive fracture and crushing.

II. Llangefni "Syncline."

Crossing the Carboniferous strata of Malldraeth Marsh, we come to an altered and contorted group of rocks which bear a superficial resemblance, especially in their colour, to the Menai schists, and have hitherto been regarded as a part of the same group. But on a careful examination of the lithology of this series, fundamental differences are observable. Even my first day's work in the district convinced me of the existence of Pebidian rocks of the St.-David's type; and fuller working-out of the area brought to light analogies with other Pebidian localities.

Slaty rocks occupy only the south-eastern side of the apparent syncline lying between the Carboniferous on the south-east and the granitoid band on the north-west, the north-western side being composed of gneissic strata. The two groups are brought together by a fault or faults; but as they dip towards each other, an apparent basin is formed (see section near Aberffraw, Pl. VIII. fig. 2).

a. *Slaty Series.*

1. *Llangristiolus Grits and Slates.*—The lowest beds I have observed are exposed near the Llangristiolus turnpike. The rock is clearly bedded; but its lithology is obscure, and the jointing is so close that clean fractures are hard to get. It appears to be a quartzo-felspathic grit, altered into a sort of hälleflinta. Some bands are coarser, grains of quartz and felspar being visible to the naked eye. A similar rock is common in the Pre-Cambrian rocks of the Church-Stretton district (Shropshire).

A little further to the north, near Cerrig ddwyffordd, a quarry-section is very interesting. At the base is a purplish grey felspathic grit (Note 42, p. 235). This is overlain by a pale-green slaty rock of Charnwood type, associated with, and apparently passing into, a sort of porcellanite (Note 43, p. 234), singularly like a rock at Caer bwdy, St. David's. The Charnwood facies of these varieties is also noted by Prof. Bonney. The section is capped by a repetition of gritty bands. The dip is northerly, at from 40° to 50°. Similar rocks are exposed in neighbouring fields.

2. *Llangefni Conglomerates and Shales.*—To the west and north-west of the Llangristiolus sections are several exposures of a greenish conglomerate. It is seen on the Holyhead road, near Waen hir, and north of Cerrig ddwyffordd, at the arrow mark, but is very fully exposed in the railway-cuttings north-west of Llangefni, the enclosed fragments, weathering white, being clearly visible even from the railway carriage. The matrix is green shale. The pebbles are very varied, the following being the principal types:—quartzite, common; pinkish grit (Note 38, p. 235) of quartz and felspar; greenish felspathic grit; and green and grey hornstone. Of these, quartzite is the only ingredient which is certainly foreign to the slaty series; the others are such as are found in some part of the group. The conglomerate would then seem to have originated in contemporaneous denudation, such as is common in volcanic rocks, together with the wearing-down of a preexisting land composed of quartzite.

Interstratified with the conglomerate are beds of purple and green felspathic shale, with some bands of hornstone. The resemblance of these rocks to the St.-David's types is unmistakable.

The road-sections in this district display a prevailing north-west dip; but the more complete exposures in the railway-cuttings reveal frequent undulations, so that the thickness is not great.

A similar group, probably on the same horizon, is well displayed in the cuttings east of Bodorgan station, 6 miles south-west of Llangefni. The prevailing rocks are purple, green, and grey ashy shales, with some felspathic breccias. Conglomerates occur containing pebbles of felsite, in which microscopic examination (Note 39, p. 236) reveals a very interesting resemblance to modern lavas.

Associated with the shales at Llangefni station is a thick bed of quartzose grit, such as might have been produced by the denudation of an ancient quartzite.

Still following the strike to the south-west, we find the slaty series well exposed at numerous points on the coast from Bodowen

round to the Aberffraw sands. On the shore near Bodowen, Llangefni conglomerate is underlain by grit. On the east side of Porth twyn mawr, it overlies slaty rock, and contains large unrounded pieces of it. The same conglomerate, repeated by folding, occurs at intervals as far as the Aberffraw sands.

Quartzite occurs in lenticular bands in pale-green slate west of Porth Cadwaladr. This association is also very common in Northern Anglesey.

Near, or at, the base of the slaty series of this district are several masses of quartz rock of obscure origin. The most prominent of these is the craggy hill * called Craig fawr, above Llangefni. It is a massive white rock, in which the quartzite structure is still apparent. It is surrounded by Carboniferous strata, and it probably formed an island in the Carboniferous sea. The same rock may be traced at intervals along the strike to the south-west. One conspicuous crag of it is seen at Bethel, north-east of Bodorgan station. I can only suggest that we may have in these bosses the remains of an ancient land, from which the Pentraeth gneiss derived its angular fragments, and the Llangefni conglomerate its rounded pebbles and its quartz grits.

3. *Cerrig-Ceinwen Slaty Group.*—These rocks lie to the north-west of the last group, with the same (north-west) dip; and as they present important lithological differences, they can hardly be repetitions.

North east of Cerrig Ceinwen, a little south of the Holyhead road, are green and purplish slaty beds. Some bands are calcareous; and the formation on the whole resembles the rocks forming the ridge at Wugan bach. Large nodules of jasper are abundant. Their origin is not absolutely clear; but I am disposed to regard them as included pebbles. The beds have a high dip to the north-west. On about the same strike to the south-west are pale green ashy bands. Close to Cerrig-Ceinwen church, to the north, are prominent ridges, composed of a greenish rock, so tough that it was difficult to obtain a specimen. It has a superficial resemblance to a greenstone, but is undoubtedly an indurated sedimentary rock, presumably an ash. It suggested the "greenstone" of Clegyr Foia, St. David's.

A fine exposure in a quarry west-south-west of Cerrig Ceinwen, on perhaps a little lower horizon than the jasper conglomerate, deserves attention. The rock is typical of the slaty series of Anglesey. In the field it appears as a pale green slate or indurated shale, sometimes faintly banded. Comparing it with some of the Charnwood slates (Note 44, p. 234), the only difference I could detect was that the Anglesey type displayed a slight lustre indicative of incipient metamorphism. It sometimes passes into a rock in which the alteration has been carried further, sometimes into a sort of hornstone. The dip is still to the north-west.

At Bod enlli we are apparently on the horizon of the jasper conglomerate. The conglomerate itself is not exposed; but we have limestone, purple slates, and green breccias and shales, not unlike those associated with the jasper.

* Coloured "greenstone" on the map.

Over a mile to the west-south-west, at Cerrig engan fawr, there is a considerable exposure of a very tough, green, ashy-looking rock, similar to the variety north of the church.

All the above rocks dip to north-west; but a little further to the west, at Ty'n-y-buarth, the beds dip to south-east. The strata at this locality are highly contorted on a small scale, and are very similar to the gnarled rocks east and south-east of Amlwch, the alteration, as in that district, having proceeded further than at Cerrig Ceinwen. In all other respects these altered rocks resemble the Cerrig-Ceinwen slates.

b. *Gneissic Series.*

The band of gneissic rocks is hardly a mile in width at Bodwrog, where it is separated from the Pebidian by a faulted strip of Palæozoic shale; but it gradually expands to a breadth of over two miles in the coast section on the south-west. The fault separating it from the slaty series runs from near Bodwina, north of the Holyhead road, in a south-south-west direction, losing itself under the sands of Aberffraw. On the west of the sands are nothing but schists; on the east are nothing but rocks of the slaty series. It will be necessary to describe two sections across this zone.

1. *Coast Section from Porth Nobla to Aberffraw Sands.*—On the coast, west of Porth Nobla, is a considerable exposure of greenish felspathic rock similar to the hälleflinta seen on the strike to the north-east, near Ty Croes. It appears to form an anticline. On Porth Nobla it clearly dips south-east, and passes gradually up into grey gneiss. To the west it presents but slight indications of stratification; but as we proceed eastward planes of separation gradually appear, which, at first obscure, become more and more distinct, till the rock is undistinguishable from a true gneiss. I have long since noticed an unbroken passage between hälleflinta and gneiss in the Wrekin; and Dr. Hicks has recorded the presence of an incipient foliation in the hälleflinta ("Arvonian") of St. David's. The grey gneiss soon passes up into quartzose gneiss, quartz-schist, and quartzite. These siliceous types, which are of much theoretical interest, occur in great force, and form the main part of the headlands of Mynydd baen and Pen y cnwc, which project between Porth Nobla and Porth Trecastell. On the west side of Porth Trecastell is a band of calcareous quartz-schist, or quartzose foliated limestone. The silicate appears to be talc or chlorite. There is a break in the section at the centre of the bay; but as the calcareous schist reappears on the east side, there can be but a slight break, if any, in the succession. Overlying the last-named rock is a considerable exposure of decomposed grey gneiss interstratified with bands of quartz rock, the whole being much contorted and broken. A greenstone dyke appears here. After a few undulations, the decomposed rock disappears, and ordinary white and grey gneiss, sometimes rather quartzose, dips steadily to the south-east for some distance. Then comes in the well-known green schist of the Menai type, which is continued to the Aberffraw sands. It is well

seen on Porth gwyfen with the normal south-east dip. On the shore, near the church, an undulation brings up grey gneiss. Then the south-east dip is resumed; but at Trwyn du, just before reaching the Aberffraw estuary, the beds turn up to the south-east, and a syncline is formed. The succession described is shown in fig. 4.

2. *Section on the Railway from Ty Croes to Bodorgan.*—The succession is substantially the same as the last; but it furnishes one or two additional facts. At Felin bont is the hälleflinta first noticed by Dr. Hicks, who rightly conjectured, as the last section proves, that it passed to the south-east beneath the schist at Ty Croes*, though he was in error in placing it above the granitoidite, which lies at the very summit of the gneiss series. West of Ty Crocs quartzose schist is exposed in the road.

Coming to the railway-cuttings, we find to the east of the station a good section of grey quartzose gneiss (Note 34, p. 233) dipping south-east. This rock is one of the most prominent types seen west of Porth Trecastell. Grey and white gneiss are seen for more than a mile with the same dip. In the cutting from near Bodgedwydd to near Graig bach, the grey gneiss grows gradually darker and darker, and passes without a break into the dark green Menai type, which is continued to the end of the exposure. The average dip is 40° to south-south-east. Leaving the line, we find in a road-section north-east of Tre' Iddon that the dip of the dark schist has changed to the north-west. East of this point we come almost at once to the slaty beds and conglomerates of the newer series.

The railway-section is thus seen to agree precisely with the succession on the coast. In some points it is less complete; but it displays very clearly the passage of the grey into the dark schist, so well seen in the Menai anticline.

3. *Distribution of the gneissic Subdivisions to the North-east. Hälleflinta.*—This band gradually narrows towards the north-east, being cut out by the fault that brings the lower part of the gneiss series against the granitoidite; so that at Gwalchmai it is hardly visible, and at the section† north of the Holyhead road the grey gneiss is in immediate contact with the granitoidite. Some of the gneissic rocks of Gwalchmai display a transition towards the hälleflinta types.

Quartz-schist. This zone is not well exposed near Ty Crocs. To the north-east it is seen at Melin Ddrydwy and Glan'rafon; but it may be best studied at Gwalchmai near the church, on the road to the south-west of the church, and on the Holyhead road. In the last locality the granitoidite is brought against it by the fault. The dip is to the south-east, except on the Holyhead road, where it is reversed. There is probably a broken anticline at this point. The prevailing

* I was at first disposed (Geol. Mag. March 1880, p. 123) to associate this hälleflinta with the granitoidite, since similar rock, together with quartz-felsites, is included in that group; but the coast-section has cleared up several difficulties.

† Geol. Mag. March 1880, p. 124.

type is a true quartz-schist, sometimes passing into a quartzose gneiss. As it was important to critically compare this rock with the quartz rocks of Holyhead and Bodafon Mountains, I have had four specimens cut; and Prof. Bonney appends full descriptions (Notes 25–28, p. 233).

Grey Gneiss. From the section east of Ty Croes station, this band may be traced to the north-east, forming the low ridge from Tal y llyn to Gwalchmai. Passing to the east of Gwalchmai church, it is well exposed about Bodwinafawr, and on both sides of the marsh (Cors Bodwrog) and pool. At Bodwrog church it is in contact with granitoidite, the quartz-schist having in its turn been cut out. In the ridge to the east of the church the gneiss is interstratified with a highly crystalline limestone, or calcite-schist (Note 51, p. 236). From the microscopic description it will be seen that this rock resembles the quartzose limestone of Porth Trecastell; and it is probably on the same horizon. The normal south-east dip is preserved as far as the old Holyhead road, north of the marsh; but near here a change takes place, and black Palæozoic shales come up to the granitoidite.

Dark Schist. This zone is not well seen north of the Holyhead railway. The fault which limits it on the south-east gradually cuts it out, so that east of Gwalchmai the slaty series approaches the grey gneiss. The gneiss is exposed at Pen bryncle, dipping south-east; and half a mile to the south-east, near the $\frac{12}{13}$ milestone on the Holyhead road, we find green slaty rocks with a north-east dip.

III. Central Zone.

This band extends across the island from sea to sea. It is the most complicated part of this broken and contorted area; but by steady attention to the lithology, assisted by some stratigraphical indications, clear results may be secured.

a. *Slaty Series.*

In following up the gneissic rocks towards Bodafon Mountain in order to ascertain the relation between the gneissic and quartz groups, I was surprised to find an area of slaty rocks between the two. At Plâs Llanfihangel dark gneiss and granitoidite dip to the south-west; and a little further to the north, at Ma'n-addwyn, felspathic shales dip as if they would pass below the gneiss. The rock is of a typical St.-David's type, and unquestionably belongs to the younger series. High up on the south-east slope of the mountain are similar rocks dipping south-east. The dips in both cases being *away from* the quartz rock, it was natural to infer that the shales rested immediately upon it. Further examination proved that such was not the case.

At the south-west end of the quartz ridge north-west of Ty'n-llidiart the flanking rock is a sort of hornstone, banded pink and green, of a common Pebidian type. Approaching the hill, the hornstone is seen to dip away from it to the south-west; but surmounting the low ridge made by the hornstone, the beds are observed to roll

over and plunge directly towards the quartz at the very junction. A little further to the north, above the farm, the evidence of discordance is, if possible, still clearer. In the quarry is a good section of a greenish slaty rock, with the beds striking directly at the quartz forming the ridge at a distance of about 20 yards.

It is thus evident that the slaty series is faulted against the quartz group of Bodafon Mountain.

b. *Gneissic Series.*

1. *Bodafon Mountain.*—This mass cannot be brought into direct stratigraphical relation with the gneiss group, for the reasons just explained; but the lithological resemblance of this rock to the quartz-schist of Gwalchmai and Mynydd baen is so close as to render the correlation highly probable. In hand specimens some of the varieties are undistinguishable. Prof. Bonney, who was not aware of my views when working on the specimens, groups a typical variety (Note 29, p. 233) from the summit of the mountain with the Gwalchmai schists. The rock of the western ridge, which is a little more schistose, is also closely represented in the south-western localities. The inlier, surrounded by newer Palæozoic rocks, which lies to the south-east is precisely similar to the eastern part of the hill.

2. *Section between Llangwyllog and Llanerchymedd.*—The succession between these points is similar to that of the coast-section between Ty Croes and Aberffraw; but the granitoidite is wanting in the latter, and the dip is reversed, so that the two sections represent the two sides of a broken anticline.

The *granitoidite* occupies a large area south of Llanerchymedd. Round Coedana is a grey variety, rather small-grained. To the south, at Rhydgoch, it is much coarser, consisting of fragments of pink felspar in a matrix of smaller bits of quartz, felspar, and chlorite. The older geologists would have called it a porphyritic granite.

The *dark schist* is exposed about half a mile further to the south, at Glanrhyd, being the band of "greenstone" of the Survey. Prof. Ramsay originally suspected the metamorphic origin of this rock; and, after microscopic examination, Prof. Bonney is disposed to consider it a hornblendic gneiss, containing felspar, epidote, hornblende, and some quartz, the felspar being decomposed, and the whole a good deal "messed." Any obscurity arising from such an altered rock is removed if we follow the strike to the north-east. To the south-west of Graig llwyd there is a good exposure of hornblendic gneiss interstratified with granitoidite. The gneiss sometimes passes into hornblende-schist. The hornblende is well crystallized; and the alteration is very slight.

The *grey gneiss* is well seen about two furlongs south of Glanrhyd, in a quarry north of the stream. The dip is high, to the north-west; and the rock is of the ordinary type.

No rock is seen on the road for two or three furlongs to the south; but north of Llangwyllog church there is a slight exposure of *hälleflinta* too small to display dip. There is room for the

quartz-schist between this rock and the grey gneiss; but I cannot affirm its presence.

3. *Area south-east of Paris Mountain.*—The gneissic rocks of this district are on the north-easterly prolongation of the strike of the central zone; and there is no doubt that they belong to the same series: the dip, the succession, and the prevailing rock-types are the same.

On the coast between Dulas Bay and the fault north of Porth lygan the succession is not satisfactory, owing to great disturbance. South of Porth lygan the shore is mainly occupied by sandstones and conglomerates, presumably of newer Palæozoic age, deposited on an eroded surface of gneiss, and sometimes wrapping round little promontories of the older rock. The prevailing dip is easterly. On Porth lygan the gneissic series is well exposed. Grey gneiss, dark-green schist, granitoidite, and quartzite (all the types which occur on the strike inland) lie in confused, contorted and shattered masses. At the north of the bay the rocks are less disturbed, and dip to the north-west. Black Ordovician (Lower Silurian) shales are faulted down to the north, resting, in a clear coast-section, against the granitoidite.

Between Llanwenllwyfo and Nebo the succession is more distinct. Thin-bedded gneiss is seen at several points north-west of Llanwenllwyfo and north of Plâs uchaf; the overlying green schist is well exposed around Rhos manarch; and the capping granitoidite, with associated schist-bands, forms the ridge between Nebo and Ty-Newydd, the whole dipping to the north-west. In two quarries south-east of Nebo there is well exposed a strong band of quartzite and quartzose conglomerate, similar to some of the masses on the coast. I have elsewhere* given reasons for believing that this is the equivalent of the quartzose conglomerate of Twt Hill; and I stated that in these quarries the rock is unconformably overlain by black shales of (at least) Bala age. If the shales are Tremadoc or Arenig, as Prof. Hughes has since maintained, the fact is still more strongly confirmatory of the Archæan age of the quartzite. As the point is important, I submit a section (figs. 5 & 6) from each of these quarries.

Since this quartz-rock is Precambrian, is conformably underlain and overlain by gneissic strata, and occurs on the coast in the closest association with gneiss and granitoidite, there can be no hesitation in referring it to the older Archæan series. It must not, however, be confounded with the quartz-schist of Bodafon Mountain, which is lower in the succession.

Granitoidite and dark schist are found along the ridge to the west, and at the base of Paris Mountain. I have not examined the latter locality; but Mr. Allport kindly allows me to use some notes made by him in May 1868. The numbers refer to specimens now in the British Museum.

"443. Fine-grained granite? South-east flank of Paris Mountain.

"444. Granite? 100 yards from last.

* Geol. Mag. March 1880, p. 118.

"338. Hornblende-schist, passing into a more compact rock (339), not schistose, or very slightly so; and this, again, into hornblende and felspar rock, very similar in appearance to that at Malvern (340).

"This is an interesting case, as the above varieties were taken from different parts of the same large block. As in Malvern rocks, epidote occurs near the joints. No. 340 might be called hornblendic gneiss; the felspar is well crystallized in many parts of the mass. In this place there is also hornblende and mica rock; and in some parts hornblende and felspar occur in separate layers. The granite has a gneissose structure; and to my mind the evidence is clear that the whole form a series of metamorphic rocks."

I am glad to quote confirmatory evidence by so competent a lithologist, and trust that it will be unnecessary to multiply refutations of the old "granite-vein" hypothesis.

4. *Structure of the Zone.*—For structural purposes it is necessary to include in this band the gneissic area between Ty Croes and Aberffraw. The whole forms a complex and shattered anticline. A central fault margins the granitoidite on the east from Caernarvon Bay to a mile north-east of Bodwrog; then it curves a little to the east, and, passing near Llangwyllog, leaves room for the underlying gneisses. The strata dip in opposite directions on each side of the fault. This dislocation thus appears to pass along the summit of the anticline; but it does so obliquely, permitting the south-east side of the arch to open out towards the south-west, and the north-west side to expand towards the north-east; so that we have an almost complete section between Llangwyllog and Llanerchymedd as we have between Porth Nobla and Aberffraw, but with the opposite dip.

The large area occupied by the granitoidite may seem to require explanation. As this rock rarely exhibits bedding, its relations are frequently obscure; but, fortunately, in the district between Gwalchmai and Llechyn farwy the dark Holyhead schist, which immediately underlies it, is brought up by repeated undulations. Near Gwalchmai, for example, the granitoid rock dips north-west; but to the west it is thrown off in opposite directions in the Craig-yr-allor anticline. The granitoidite is, then, a band of no great thickness, repeated by contortions. There is also evidence of repetition by faults.

The generalized section (fig. 1) represents the relations of the principal rock-groups in Anglesey.

IV. Northern Area.

This district is bounded on the south by the curved fault which, starting from near Carmel's Point on the west, passes round by way of Llanfflewin and Paris Mountain to the east coast at Porth-y-corwg. The rocks are very much contorted and broken; but there appears to be, on the whole, an ascending series from the fault to the north coast. The dip is generally to the north; but on the west it is to the north-east.

1. *Volcanic group of Paris Mountain.*—The chief types of this

ridge are a felspathic breccia and a compact felspathic rock like hornstone; but both varieties are quite distinguishable from any other rocks in Anglesey. At the east end of the hill, by the Pensarn chapel, the breccia is well exposed. The fragments, some of which are a yard in diameter, are a very compact felstone; and the matrix is a sort of greenish ash. The rock, as a whole, reminded me of the compact breccias at Clegyr Bridge, St. David's. Prof. Bonney has since examined a slide; and he is of opinion that it exhibits both perlitic and fragmental structure and is in all probability a rhyolitic ash. The dip of the series is to the north, agreeing with that of the adjoining slaty group. About 100 yards to the east of the chapel, and therefore on the same strike, is a knoll composed of a pale-green and purple rock, very compact, almost like jasper. Under the microscope (Note 53, p. 236) it is seen to be a trachyte, probably from a lava-flow, and is, in Prof. Bonney's judgment, as modern in its appearance as the rock composing the enclosed pebbles near Bodorgan. The purple variety is not unlike some of the flinty felstone common in the Precambrian of Shropshire. From lithological characters the Archæan age of this group appears not improbable, though it must be conceded that it does not resemble very closely the volcanic group south of Bangor. Field work throws little light upon the problem. On the north side the ridge is bounded by a fault; and at the base of the southern escarpment black shales seem to pass conformably under the volcanic group. The two rocks appear within three or four feet of each other, dipping in the same direction into the steep face of the hill. There are, however, no signs of a passage between the black shales and the compact felspathic rock. The appearance of conformity might be produced by faulting, accompanied or followed by lateral pressure; and there are abundant proofs of both in the district; but, under the circumstances, I hesitate to include this group in the slaty series.

2. *Chloritic Schists of Mynydd Mechell.*—This group is the "foliated grit" of Ramsay. In the field it has the appearance of a quartzose grit, with chlorite covering lamination surfaces; but Prof. Bonney, after microscopic examination, regards it as a true schist (Note 45, p. 234) of the Holyhead type, though he admits that the chloritic constituent is "rather minute." These rocks are much contorted, and are frequently penetrated by dykes of felstone and dolerite running with the strike. At a higher horizon, at Cas Clock and west of Rhos-y-pill, the rock is an undoubted schist with silvery lustre (Note 46, p. 234). Some of the strata north-east of Paris Mountain are not unlike this schist, as may be seen at Cerrig, on the Amlwch road.

It is important to observe that Prof. Bonney agrees with me in recognizing (Notes under C, p. 234) a difference between these schists and those of the gneissic districts; but in such a broken country it is difficult to prove that these rocks should go with the slaty series. My reasons for so associating them are the following:—

(1) The rocks are not uniformly foliated. To the west of Cas Clock, for example, chloritic schist is overlain in the same quarry

by hard grits. In the same neighbourhood are bands of hornstone, similar to ordinary Pebidian types, associated with schist.

(2) These rocks appear to pass up through less altered varieties into slightly metamorphosed grits and shales, as seen south of Llanfechell and in localities to the east.

(3) The alteration is not carried so far as is usual in the older series.

(4) In the undoubted slaty districts, as west of Cerrig Ceinwen, the rock frequently undergoes partial metamorphism, and bands occur which might almost pass for true foliated schists.

(5) This area is scored with intrusive dykes. I do not suppose that these are the cause of metamorphism; but they indicate the proximity of a source of heat, which may have been concerned in the change.

3. *Llanfechell Grits.*—The altered rocks of Mynydd Mechell appear to pass to the north into a series of green grits, well exposed round Llanfechell. This rock has undergone much alteration, to which probably the colour is due. Microscopic examination (Note 47, p. 234) brings to light the important result that it is "almost certainly derived from the older gneissic and schist rocks of this region of North Wales." These grits are also seen on the strike to the south-east near Bodewryd.

4. *Rhosbeirio Shales.*—West of Rhosbeirio church, and in a quarry near the farm, are very interesting exposures of felspathic rocks of the true St.-David's type. These shales are soft, well laminated, and fine-grained; but here and there are thin seams of grit like the variety just described. While the body of the rock is but slightly altered, the gritty bands have a very schistose look. The prevailing colours are pale green and purple; but there are also some beds of a soft yellow shale, like a common variety in North-western Anglesey. The dip is to the north at 30°. Under this group, at Nant-y-cyntin, slaty beds of a more altered character, intermediate between these shales and the Cas-Clock schist, are seen.

5. *Sharply contorted Group south-east of Amlwch.*—At Crogan goch and on towards Llaneilian are exposed the remarkable rocks described and figured by Prof. Ramsay. The foliated structure (Note 49, p. 234) of these slaty-looking beds is not very evident to the naked eye. Similar rocks compose the tongue-shaped promontory of Point Ælianus; but sometimes contortion is wanting. At the base of the promontory the beds are gritty and partially altered (Note 48, p. 235).

6. *Amlwch Slates and Cemmaes Limestones.*—South of Amlwch, near Crogan goch, the last group, with the intervention of an ashy band, is succeeded by uncontorted pale-green chloritic slaty beds (Note 50, p. 235), which are continued to the coast and all along the west side of Bull Bay to Ogo' goch. The dip is steadily to the north at a moderate angle; and the thickness must be considerable. Towards the west, on Porth wen, bands of limestone and quartz-conglomerate come in; and further west, on Cemmaes Bay, limestone and quartz rock predominate over the slaty beds. I am not certain

that the Amlwch and Cemmaes groups are on the same horizon; but the evidence appears to point in that direction. The limestone (Note 52, p. 236) is very similar to a rock at Llanfaethlu; and the associated slaty beds are alike in both localities; but it would be rash to correlate the groups.

The northern area (omitting Paris Mountain) is thus seen to consist of chloritic schists, felspatho-quartzose grits, felspathic shales, chloritic slates, quartz-conglomerates, and grey limestones, with some limestone bands on more than one horizon. In such a shattered district a true succession can hardly be indicated. North of Paris Mountain some of the horizons are probably faulted out of sight, and it is difficult to correlate the rocks of this district with those further west. Most of the groups appear to pass into each other, either vertically or laterally; and I cannot avoid the conclusion that they all belong to the same epoch.

V. North-western Area.

In Western Anglesey are two well-marked groups of strata, which I regard as the equivalents respectively of the Gneissic and Slaty series. They are brought together by a fault.

Porth-y-defaid Fault.—This dislocation is situated on the west coast, about midway between the northern and southern extremities. It is well seen on the shore, striking inland to the east. Greenstone is erupted along the line of junction, and alters the strata for a short distance on each side. South of the fault are thoroughly crystalline quartzo-micaceous and chloritic schists dipping north-west; while close at hand on the north side green ashy shales dip north-east. This fault is the boundary between the two series; for true schists with a south-west strike occur everywhere to the south, while a comparatively unaltered group, with a prevailing northerly dip, stretches right up to the north-west corner of the island.

Section from the Fault to Pen bryn'r Eglwys.—Proceeding northward, we find at Trefadog ashy shales dipping north-east. In the quarries north of Llanfaethlu church is a good section of grey limestone and pale-green ashy slate with easterly dip. The former is compact, and apparently as unaltered as any Palæozoic limestone. A careful search revealed no trace of fossils. The slaty rock is of a common Anglesey type; and the whole group is like the Cemmaes series. About Llanrhyddlad exposures are numerous. At Porth Swtan, on Church Bay, is a considerable thickness of yellowish felspathic slate and breccia. The dip is north-east, with slight contortion on a small scale. Higher beds are seen in quarries at Rhyd Ngharad; the rocks are brecciated in part and very felspathic. Greenish colours predominate. One variety, a pale-green slate, contains cubic pyrites. On about the same horizon, at Ogo Lowry, are green brecciated rocks more highly indurated.

The district between Ogo Lowry and Penbryn 'r Eglwys is one of the most faulted parts of the island; the section consists of alternations of Archæan and Palæozoic rocks, repeated by faults, and dipping to the north. The wedges of dark shale let in amongst the older group are very clearly seen in the sea-cliffs. The younger shale, of

course, frequently appears to pass under the felspathic series. Such facts suggest great caution in trusting to dips in areas where the faulting is not clearly seen. The lithology here, as generally in Anglesey, is the true guide. The Precambrian chiefly consists of felspathic breccia. The fragments are usually of similar composition to the matrix; but some are of quartzite. The felspathic fragments weather out sharply where the cliffs are washed by the spray. On the whole this rock strongly suggests the breccia near Nun's Well, St. David's. Good exposures are seen at Ynys y fydllyn, Porth yr hwch, and west of Pant yr Eglwys. The thickness, owing to such frequent faulted repetitions, probably is not great.

The section at Pen bryn'r Eglwys is of much interest. In this great headland, which juts out at the north-west corner of Anglesey, are rocks which are described in the section of the Survey Map as "gneissic rocks pierced by granite veins;" and these are represented as passing on the south into "metamorphic foliated rocks." The latter are the felspathic shales and breccias already noticed. The description of the former also requires modification.

The breccias pass up into the southern slope of the headland, where they are succeeded by a band of quartzite. This is overlain by a considerable thickness of greenish felspathic beds of ordinary Pebidian type and not much altered. The highest ridge of the promontory consists of this rock. Following these strata across the strike to the north, they are seen gradually to change, the rock putting on a glazed aspect, and mica appearing in small quantities on the lamination-planes. This altered material soon passes into thoroughly foliated gneiss and granitoidite.

It was rather startling to find true metamorphic rocks associated with comparatively unaltered felspathic beds of the newer series. The granitoidite is very similar to that of the older gneiss; and my first impulse was to refer it to that group. In such a shattered district as Anglesey, especially in such an area as its north-west corner, a faulting-up of the older series seemed not unlikely. But, after careful examination, I found it impossible to accept this supposition. The transition between the unaltered rock and the schists is gradual and complete. A close comparison furthermore revealed lithological distinctions between the gneiss of the two series, the most important of which is a difference in the colour and lustre of the mica.

The cause of metamorphism was not apparent. The "granite veins" of the Survey are probably the granitoid bands in the gneiss. Some quartz veins running across the cliffs may have suggested the intrusion of granite. As this metamorphosed mass occurs in the neighbourhood of the Mynydd-Mechell schists, the alteration in both cases may be due to the same general cause.

VI. Western Area.

All the rocks south of the Porth-y-defaid fault and west of the Palæozoic area belong to the older series.

1. *The Mainland.*—This district is chiefly occupied by green chloritic schists (Note 37, p. 234) similar to the rocks described from the Menai anticline, Aberffraw, Craig yr allor, and east of Paris Moun-

tain. The dip is usually to the south-east; but the beds frequently roll over to the north-west, as may be seen south of Porth twynmawr, and at Caer ceiliog on the Holyhead road. There is no doubt that these schists represent the dark green band which in the central zone underlies the granitoidite.

2. *Holyhead District.*—Chloritic schists are well seen at many points in and round the town. A typical specimen from Porth felin (Note 36, p. 234) is of the same character as the schist at Porth y defaid. The strike is to the south-west; and undulations are numerous. These rocks are separated from the quartz group by faults: one, on the south-west, runs from the south coast, at Porth y corwgl, to the south end of Holyhead Mountain; and another, on the north-west, lies along the south-eastern base of the mountain and cuts the coast at Porth yr Ogof.

Porth-yr-Ogof fault.—Prof. Ramsay * states that the "quartz rock" dips under the "foliated schists;" and he gives a section in support of his opinion. This view would have greatly simplified my work; but on visiting the spot I was disappointed to find that the two groups were brought together by a fault. There was a notch in the cliff; on one side was quartz rock, and on the other green schists (Note 35, p. 234), with no signs of a passage. The break was filled in with fallen rubbish. It was very fortunate that this dislocation was discovered, as it compelled me to seek the true succession elsewhere.

Holyhead Mountain.—The microscopic examination (Note 31, p. 233) of a typical specimen of the quartz rock from the great quarry shows that it is a true quartz-schist of the same type as the Bodafon, Gwalchmai, and Mynydd-baen quartz groups. The structure of the mountain is interesting. Ascending the south-east slope, separation-planes are seen to dip to the north-west at about 80°; but on the north-west side the dip changes to south-east at the same angle. The planes are not close and even, as in slaty cleavage, but they cause the rock to split in large thick flat flakes. This difference is doubtless due to the coarseness of the material; and the planes must represent true cleavage. The cleavage-strike agrees with the strikes of the contorted bedding and of the ridge.

The Holyhead district is thus brought into clear comparison with other parts of Anglesey. The chlorite-schists undoubtedly represent the dark schist which underlies the granitoidite in the central zone; and the quartz-schists may with the highest probability be placed on the same horizon as the foliated quartz rocks of Bodafon and Gwalchmai. The absence of the grey gneiss is easily explained. On both the west and south the junction between the quartz and chloritic groups is a fault; but the two formations dip in the same direction, and the downthrow is apparently on the side of the chlorite-schist. As the latter group is repeated in numerous shallow curves, there is no reason why the grey gneiss should appear at the surface, as it does amidst the deeper undulations of the Menai anticline.

* Geology of North Wales, p. 183.

The chloritic rocks of this area are rather more quartzose than in most Anglesey localities; but they resemble some of the varieties in Mynydd Llwydiarth, and there are indications in both districts that a source of quartz-derivation was not far distant.

3. *Rhoscolyn District.*—The south-eastern half of Holyhead Island is similar in structure to the Holyhead area; but the rocks are affected by an upheaving force to the south, so that the prevailing dip is to the north. The green schists, which occupy the chief part, need no further description. The southern fault, which separates the quartz and chloritic groups south of Holyhead, passes under the sea, and holds the same relation near Rhoscolyn. It is first seen near Bwa du, and again appears on the coast to the south-east at Borth wen, passing in its course near Rhoscolyn church, where the quartz-schist (No. 32, p. 233) is exposed, dipping northerly. A few yards to the north the chloritic group dips in the same direction, at about the same angle. At Bwa du the junction is well seen, both series dipping northerly, the green schist at a lower angle than the other. The quartz group forms an elevation, Mynydd Rhoscolyn, as is usual in Anglesey.

At Borth Saint, south of Bwa du, the contortion is intense. There is evidence, from the folding of quartz veins, that the rock has been squeezed to one fourth of its original bulk. At one spot there is a very curious specimen of ripple-mark, distorted so as to be almost unrecognizable. Quartzite dips to the north, and is underlain by soft schist. The under surface of the former overhangs, and is covered with rounded projections, which are evidently the squeezed casts of ripple-marks. The schist was the mud which received the impressions of the ripples; and the quartzite represents the sand which covered in and preserved the marks. I have elsewhere * figured and described the above phenomenon. It is important to record ripple-marks in so ancient a formation.

South of the last locality is a considerable thickness of chloritic quartz-schist (Note 33, p. 233).

B. Summary of Results.

I. Distribution of the Rocks.

[See Map (Pl. VIII.) and Fig. 1.]

a. *Gneissic Series.*

1. *Geographical Distribution.*—This series occupies the greater part of the Menai anticline. It reappears west of the Llangefni slaty area, and forms the whole of the central zone, except the faulted mass south-west of Bodafon Mountain. It then reemerges west of the Palæozoic, and covers Western Anglesey south of the Porth-y-defaid fault. About three fifths of the area coloured "altered Cambrian and Silurian" consists of gneissic and schistose rocks.

* 'Science for All,' part xxxi. pp. 203 and 205.

The *hälleflinta* forms a band extending from Porth Nobla to near Gwalchmai. It is probably represented north of Llangwyllog.

The *quartz-schist* extends on the strike from Mynydd baen to Gwalchmai. It may occur in its place north of Llangwyllog; but it emerges in the craggy mass of Bodafon Mountain and in the small inlier to the east. In Western Anglesey it forms the elevations of Holyhead Mountain and Mynydd Rhoscolyn.

The *grey gneiss* is brought up through the dark schist on the western side of the Menai anticline at Gaerwen and east of Pentraeth. In central Anglesey it runs from near Porth Trecastell to north-east of Bodwrog, reappearing soon after on the opposite side of the anticline north of Llangwyllog, and further to the west in the Craig-yr-allor anticline. To the north-east it is seen in the area south-east of Paris Mountain.

The *dark schist* occupies the greater part of the Menai anticline. It emerges west of the Llangefni "syncline," but is gradually faulted out towards Gwalchmai. On the opposite side of the central anticline it forms a band as far to the north-east as Plâs Llanfihangel, and is brought up through the granitoidite in the oval dome of Craig yr allor. It also occurs south-east of Paris Mountain. In Western Anglesey it constitutes the schistose area south of the Porth-y-defaid fault and north of the quartzose masses.

The *granitoidite* is the "granite" band of the Survey. The details are inaccurately laid down in their map at many points; but little theoretical importance attaches to these errors. There are slight traces of this rock on the west side of the Menai anticline.

2. *Stratigraphical Distribution.*—One of the most difficult problems in Anglesey was to make out the succession of the subdivisions of this group. In no single section, owing to the faulting, is the series entire; but the subdivisions are recognizable by their lithological characters; and by comparing localities the fragments are pieced together into a complete succession. The facts will be best expressed in the following table, the groups being taken in descending order:—

	1. Holyhead.	2. Craig yr allor.	3. Coedana.	4. Dulas Bay.	5. Ty Croes.	6. Menai.
Granitoidite ...	...	*	*	*	...	Traces.
Dark schist ...	*	*	*	*	*	*
Grey gneiss ...	...	*	*	*	*	*
Quartz-schist ...	*	...	?	...	*	
Hälleflinta ...	...	...	?	...	*	

The star indicates the existence of the subdivision in the locality at the head of the column. By comparing 5 with 2, 3, and 4, it will be seen that two groups are common to the four areas; and they serve to link together the lowest and highest subdivisions.

The series is probably complete in 3; but in running the section I could get no exposure between an obscure opening of hälleflinta and the grey gneiss, and I had not time to search beyond the highroad.

b. *Slaty Series.*

This group occupies four areas, viz. the small mass south-west of Pentraeth, the east side of the Llangefni "syncline," northern Anglesey, and the western division north of the Porth-y-defaid fault. The chief facts are thus summarized:—

(1) *South west of Pentraeth* (Wugan-bach ridge).
Slaty and dolomitic rocks.

(2) *Llangefni district.*
Slates (some hypometamorphic *), grits, green conglomerates, purple and green shales, hornstone, calcareous beds.

(3) *Northern district.*
Chloritic schists, altered grits, green and purple shales, slates (some hypometamorphic), quartz-conglomerates, limestones, hornstone.

(4) *North-western district.*
Yellow felspathic shales and breccias predominating, quartz-conglomerates, pale-green slates, and limestones.

I am not prepared to submit a scheme of the succession. The rocks of area 1 are not unlike some of those near Cerrig Ceinwen in area 2. Comparing 2 and 3, the rocks are similar as a whole; but the green conglomerate, so conspicuous in 2, is not seen in 3, while the quartz-conglomerates and grey limestone of 3 do not appear in 2. Portions of 3 are also altered to schist, while in 2 the transition into foliated rock is rarely complete. The felspathic breccias of 4 do not certainly occur in any of the other areas; but its quartz-conglomerates, slates, and limestones are similar to those of 3. The interesting Rhosbeirio shales in 3 have less complete representatives in 2, but are fully exhibited in 4.

The rocks of these four areas, though geographically isolated, are closely connected by their mineral and petrological characters, and I have no hesitation in placing them all in the same group. Should the chloritic schists of the north be separated from the newer series, it will not materially affect my general conclusions. The same remark applies to the small patch of gneissic rock at Bryn 'r Eglwys.

II. Evidence of Age.

a. *Relations to Palæozoic Groups.*

Gneissic Series.—It is not necessary to recapitulate the evidence for Precambrian age. The sections in the quarries near Nebo would alone be sufficient to remove all doubt.

Slaty Series.—These rocks do not clearly underlie any part of the Cambrian; they are, indeed, overlain by a purple conglomerate on the north coast, west of Tor llwyn. The pebbles of this rock are a

* The term "submetamorphic," used by some authors, is objectionable on grammatical grounds.

purple quartzo-felspathic grit; but I have no certain proof of its age.

The Precambrian age of the series may be inferred from included fragments. The rocks west of the granitoid zone are shown by the fossils collected by Prof. Hughes to be Tremadoc and Arenig. In the conglomerates west of Llanfaelog, which appear to be of at least equal antiquity, a large proportion of the pebbles are certainly derived from the Slaty series, pale green and purple hornstone and slate being the most common. It is also worthy of notice that the Harlech conglomerates of Caernarvonshire contain fragments of green and purple slate *, which must therefore be Precambrian and of no distant source of derivation.

The relations of these series to the Cambrian rocks in contact indicate the same result. At numerous points the two groups are brought together by faults; but while the Slaty series is generally more or less altered, the Cambrian shales are quite unchanged, and I have never observed the slightest indications of a passage between the two, the line of demarcation being always clear and sharp. The Slaty series must therefore have undergone partial metamorphism before the Cambrian period, otherwise it is difficult to see how the Cambrian rocks could have remained unaltered.

The black shales in some localities dip as if they would pass under the altered series; but at many points the latter also appear to pass beneath the former. In such a shattered district this evidence is worth nothing in either case, unless an unbroken sequence can be proved.

I am not prepared absolutely to deny that true Harlech rocks occur in Anglesey. There are beds, especially near Llangristiolus, which lithologically do not appear to be very distinctively Precambrian; but, as stratigraphically they are closely associated with the Slaty series, it is safer to place them in that group.

b. *Relations to each other.*

In all parts of Anglesey the junction of the two series, whenever they are in contact, is a fault. In the east and centre they generally strike in the same direction; but in the north-east (near Paris Mountain), at the base of Bodafon Mountain, and in the western district, as seen north and south of the Porth-y-defaid fault, the strikes are discordant, sometimes approaching a right angle. The much more intense metamorphism of the gneissic series would seem to point to a greater antiquity. Some additional light is thrown upon the subject by the microscope. Prof. Bonney, in note 47 (p. 234), already noticed, is decidedly of opinion that the Llanfechell grit, a characteristic variety of the newer rocks, is derived from the older series.

c. *Relations to other Areas.*

(1) *Caernarvonshire.*

Comparing the *Slaty series* with the Bangor group, the re-

* Bonney, Quart. Journ. Geol. Soc. vol. xxxv. p. 311.

semblance, it must be confessed, is not very close. Both formations are largely of volcanic origin; but the felspathic materials of the Anglesey rocks are derived from a more distant source, while the frequency of quartzite pebbles indicates the proximity of land not covered by volcanic products.

The *Gneissic series* would appear to be closely related to the granitoid rock of Twt Hill. As the normal position of the dark schists is below the granitoidite, there seems to be no reason to doubt that the green schists on the Anglesey side of the Menai Straits pass conformably beneath the Twt-Hill beds. The post-Carboniferous fault on the west side of the Twt-Hill ridge might not materially affect the true relations of the older subdivisions.

(2) *St. David's.*

Slaty Series.—The lithological resemblances between this group and the St. David's Pebidian are numerous and striking. The varieties whose Pebidian facies is most marked are the pale-green, purple, and yellow felspathic shales of Rhosbeirio, the felspathic breccias north of Llanrhyddlad and east of Bodorgan station, the tough green rock at Cerrig Ceinwen and Cerrig-engan fawr, porcellanitic bands near Llangristiolus, and hornstones of many localities. The slaty beds are less distinctively of St. David's type.

Gneissic Series.—The Anglesey granitoidite has been compared by Messrs. Bonney and Hicks with the St. David's Dimetian. If this correlation be conceded, the entire Anglesey series, from the hälleflinta upwards, must go with the Dimetian. But it must be admitted that the two groups present important differences. At St. David's the Dimetian is represented by a great thickness of granitoidite and quartzite; whereas in Anglesey the similar band is much thinner, and is underlain by a considerable thickness of gneiss and other schists.

(3) *Shropshire.*

The felspathic slaty beds of Lilleshall Hill are hardly distinguishable from some of the Anglesey rocks. The Lilleshall group is probably higher than the Wrekin volcanic rocks, which have many points of resemblance to the fragmental group south of Bangor. The purplish ash of the Wrekin, for example, is very similar to the grit at Bryn llwyd. Nothing certain, of course, can be inferred from such facts; but it is at least worthy of consideration, and the suggestion may be a guide in further inquiry, whether the Anglesey Pebidian may not represent a higher horizon than the Bangor group. Some of the gritty and slaty rocks of the Precambrian ridges east of Church Stretton also display affinities with the Anglesey series.

It is worthy of note that the Charlton-Hill conglomerate, an undoubted part of the Wrekin group, contains, amongst enclosures from the Malvern series, pebbles of rocks which more closely resemble some of the gneissic and quartzose types of Anglesey.

(4) *Charnwood.*

The slaty rocks of Anglesey are nearer in their lithological characters to the Charnwood slates than to any other formation with which I am acquainted. The resemblance was very marked even in the field; but in the case of a homogeneous rock like slate, the microscope is of special value, and Prof. Bonney's examinations (Notes 42, 43, 44, pp. 234, 235) are strongly confirmatory of my opinion.

Conclusions.

1. In Anglesey there are two Archæan groups, the Slaty and the Gneissic.

2. The Slaty series is composed of slates, shales, hornstones, grits, conglomerates, limestones, and chloritic schists, in which no definite order has been positively ascertained. The Gneissic series is divided into five groups, in which the following descending order is invariable, viz. granitoidite, chloritic and hornblendic schists, grey gneiss, quartz-schist, and hälleflinta.

3. The Slaty series is occasionally foliated, but is usually in a partially altered state: the Gneissic group is thoroughly metamorphosed.

4. The Slaty series has closer lithological affinities with the St.-David's volcanic group, the Charnwood rocks, and the Lilleshall series than with the Bangor group.

5. The Slaty series is undoubtedly Pebidian: the Gneissic series may with some probability be referred to the Dimetian.

APPENDIX.

Notes on the Microscopic Structure *of some* Anglesey Rocks.
By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

In the following notes I shall endeavour to avoid repetition by grouping together those specimens which in some important characteristics have a general resemblance one to another. I may add that, as the purpose of my examination was petrological rather than mineralogical, I have not felt bound to spend much time in endeavouring to ascertain the exact species of some microlithic minerals which are accidentally present in one or two of the slides.

A. *Quartz-Schist Group.*

Nos. 25–29, 31–34.

This group consists of a series of schistose rocks, in general highly metamorphosed, in which quartz is the most important constituent, associated with micaceous or chloritic minerals, ferrite or opacite, and more or less felspar.

The fragmental origin of most of these specimens is indubitable; but with regard to numbers 25 and 27 it is less easy to be quite sure. Their structure comes nearer to that of some microcrystalline felsites; but still I believe that I am right in ranking these also among the altered clastic rocks.

25. (Gwalchmai, p. 218.) Contains numerous grains of quartz of

rather irregular outline in a finely granular and rather earthy-looking matrix—most probably the result, in the main, of the decomposition of rather imperfectly crystallized felspar, which consists now of an admixture of earthy dust, doubly refracting clear microliths, and minute scales of mica or chlorite. The quartz grains show an indistinct banded order, and contain many minute cavities. The rock appears to have been brecciated more than once *in situ*. The older cracks are mainly filled up by quartz, the newer by calcite with a little chlorite. In one part of the slide the faulting of an older vein and subsequent infiltration of a newer one is very clearly shown. Macroscopically the rock has a resemblance to the Treffgarn hälleflinta, but under the microscope it is more gneissic.

26. (Gwalchmai, p. 218.) Is certainly of fragmental origin, showing stratification foliation. The quartz grains have fewer inclusions; there is felspar much as before, and a fair quantity of mica; most of this is of a very pale golden-yellow colour, is feebly dichroic, and gives brilliant tints between the Nicols; the rest is dull green, probably an alteration produced after biotite. Some granular matter as above.

27. (N.W. of Gwalchmai, p. 218.) More resembles 25, but is more compact. I think that it, too, is of fragmental origin, and is probably the result of the metamorphosis of a fine quartzose silt.

28. (N.W. of Gwalchmai, p. 218.) Is certainly fragmental, consisting of quartz with a fair amount of chlorite, some white mica, and a few grains (probably fragmental) of a closely twinned plagioclastic felspar.

29. (Summit of Bodafon Mountain, p. 219.) Is a quartz-schist with a fair amount of ferrite and minute chlorite (?).

31. (Holyhead Mountain, p. 226.) Also a quartz-schist with a fair amount of a pale-green mica, as above, the ground-mass consisting of this mineral with agglutinated very minute grains of quartz. In this are scattered quartz grains of larger size up to about 0″·03 diameter, clearly of fragmental origin, some having a secondary deposit of quartz on their edges. Minute cavities are common in these grains, and one or two contain some dark hair-like microliths, a grain or two of epidote, and possibly one of tourmaline.

32. (Rhoscolyn church, p. 227.) Also a quartz-schist resembling the last, but more uniform in structure; the same adventitious minerals as in the last.

33. (S. of Borth Saint, p. 227.) Another quartz-schist with rather more mica and chlorite, a few grains of felspar, and the same adventitious minerals. Numerous grains of a granular earthy mineral (? an epidote).

34. (Cutting E. of Ty Croes, p. 217.) Quartz and a white mica are the most conspicuous minerals, with an occasional grain of felspar; but a sort of granular paste in which these are imbedded, consisting of microliths of white mica and other minerals, may in some cases have replaced a felspar constituent. The rock is much altered, but, I suspect, still retains in its large grains traces of its original fragmental structure.

B. *Chlorite-Schists.*

A group of highly altered, distinctly foliated rocks, consisting mainly of rather minutely crystalline chlorite and quartz. To this belong Nos. 35–37, 45, 46, 49.

35. (Porth yr Ogof, Holyhead, p. 226.) Contains very numerous rods and granules of a black mineral, perhaps magnetite, with a little sphene or staurolite; it exhibits beautiful contortions.

36. (Porth felin, Holyhead, p. 226.) Foliation less marked; a considerable amount of ferrite is present. Original structure perhaps less uniform than in the last.

37. (Porth y defaid, p. 225.) The same remark applies to this specimen also, but its foliation is more marked. A vein of quartz and calcite.

45. (Melin pant y gwyda, p. 222.) The same; chloritic constituent rather minute.

46. (Cas Clock, p. 222.) Highly altered and markedly foliated.

49. (Crogan goch, p. 223.) The same; chloritic or possibly micaceous constituent extremely minute; beautifully foliated and contorted.

In this group, as a rule, it is more difficult to identify with probability any original constituent of the rock, owing probably to differences in chemical composition and size of the materials. Some of the quartz grains in 37, 45, 46 may, however, be original.

C. *Slaty and other not highly altered Rocks.*

In this group there has, indeed, been a certain amount of alteration, but it is only what may be termed micromineralogical. The original fragmental character of the rock is still distinct; the newer products are either extremely minute or such as result rather from *decomposition* than from *recomposition*. The alteration, in short, is of a kind which we commonly meet with in the earlier Cambrian or latest Precambrian rocks, not in the gneisses, in the conspicuously foliated schists, and in the most highly metamorphosed quartzites. Its members, then, are, as a rule, either much more modern than those previously described, or selective metamorphism must have operated upon the latter to a rather unusual extent.

43. (S.E. of Cerrig ddwyffordd, pp. 214, 232.) One of the flinty argillites or indurated imperfectly cleaved slates. Under the microscope the slide consists of a brownish-grey earthy-looking material interspersed with minute specks of quartz, felspar, and micaceous or chloritic minerals, whether original constituents or of secondary origin it is in many cases difficult to say. The "stripe," however, is well indicated, and the specimen in no important respect differs from many examples that I have examined from Charnwood and other localities where the rocks are approximately of Cambrian age.

44. (W.S.W. of Cerrig Ceinwen, pp. 215, 232.) A similar rock of slightly coarser material and a little more distinctly cleaved. Among the constituents are many scales of a strongly dichroic green mineral with a marked wavy cleavage—chlorite or some member of the provisional viridite group, probably the result of alteration of a magnesia-iron mica fragmentally present.

47. (Llanfechell, p. 223.) A coarser fragmental rock with a rather

"streaky" structure, not unlike some of those which occur in the Borrowdale series, containing numerous microliths of the viridite group, some being certainly chlorite. The aspect of the rock suggests that it has undergone considerable pressure. Many of the imbedded fragments are from about 0″·03 to 0″·06 in longer diameter. Among them quartz, felspar, altered biotite (?), and a chloritic quartz-schist may be recognized, detrital materials almost certainly derived from the older gneissic and schist rocks of this region of North Wales. Other fragments of a less certain character are present, with grains of decomposed ilmenite or magnetite and of epidote, which perhaps has replaced some other mineral.

48. (Base of Point Ælianus, p. 223.) A rock of a generally similar character; but, as the fragments are smaller, their nature (except in the case of the quartz) is less easily ascertained; the whole rock also seems slightly more altered than in the last case.

50. (Coast N.W. of Amlwch, p. 223.) The materials are more homogeneous than in the other cases; small greyish clustered granules frequent, and a vast number of microliths of a green mineral (chlorite?). These are very likely of secondary origin, but I consider the rock a true slate, and not a schist.

42. (S.E. of Cerrig ddwyffordd, p. 214.) A fine grit with much of the fibrous green (? hornblendic) mineral which I have often observed in the Charnwood rocks developed among the finer materials; the larger fragments (generally rather angular) are chiefly quartz, felspar (orthoclase and plagioclase), and a minutely microcrystalline or cryptocrystalline rock, much resembling bits of an acid lava. From certain minute peculiarities, I have strong suspicions that all three of these constituents have been derived from rocks of volcanic origin.

38. (Fragment in Llangefni conglomerate, p. 214.) A grit, consisting of subangular and rolled grains, mostly quartz, in a fine quartzose or quartzo-felspathic matrix. It is difficult in the case of rocks of this character to draw an inference as to their age and amount of metamorphism; but I believe that I am right in grouping it with the probably more modern series.

D. *Granitoid Gneiss.*

Of this rock there is one specimen from Pen Bryn yr Eglwys not at all in a favourable condition for microscopic examination. It resembles the group of coarse granitoid gneisses similar to those which I have examined from the neighbourhood of Llanfaelog rather than a true igneous rock. It consists of quartz with many minute enclosures, two felspars much decomposed, and various alteration-products probably replacing an iron-magnesia mica. One or two grains of another mineral are present, obviously much altered, which I cannot identify; possibly it may have been garnet.

E. *Crystalline Limestones.*

40. (E.N.E. of Tan y graig, Pentraeth, p. 213.) A finally granular clear rock consisting almost wholly of calcite or dolomite. Judg-

ing from the structure and optical characters, I should infer the presence of a considerable quantity of the latter mineral, and so name the rock a dolomite.

51. (E. of Bodwrog, p. 218.) Is more coarsely crystalline with an admixture of quartz grains and some silicate, which I am unable to identify with certainty; the carbonate, however, appears to be mainly calcite.

41. (At "a" of "Pentraeth," p. 213.) To the unaided eye appears less crystalline and less pure, resembling some limestones which have an admixture of volcanic mud. Under the microscope the calcite appears in rather irregular grains of fair size and rather brecciated aspect, imbedded in a streaky-looking paste composed of a pale green serpentinous mineral, of black and dark brown dust, with a little quartz, and of a clear silicate in minute granules, probably some kind of zeolite.

52. (Tau isa, N.E. of Cemmaes, p. 224.) Is moderately clear, chiefly composed of very minute granules of crystalline calcite and possibly dolomite, with occasional brown stains, and veined irregularly with more coarsely crystalline calcite. In no one specimen can I detect any distinct trace of an organism; but the first two rocks differ much from the last two, which might readily pass for members of the Carboniferous Limestone series.

F. *Igneous Rocks.*

39. (Fragment in green shale, E. of Bodorgan station, p. 214.) The ground-mass is thickly crowded with small and not very sharply defined felspar crystals, which, in their elongated form and the twinning of larger specimens, generally resemble members of the plagioclase group, interspersed with numerous minute grains of a pale green colour, of which the larger are distinctly dichroic and are probably hornblende. Small grains and occasional rod-like microliths of an iron peroxide are also present. Scattered about in the ground-mass are roundish patches of tessellated aspect, chiefly composed of crystalline quartz; one, in which the crystals are larger and by their enclosures indicate lines of growth, has calcite at the centre; this, however, as in the case of a neighbouring vein, is probably a subsequent infiltration. The majority more resemble imperfectly formed spherulites; a portion of the slide shows a distinct fluidal structure, and the ground-mass has a general resemblance to several modern lavas, *e. g.* to specimens in my collection from Astroni and the Solfatara (Phlegræan Fields).

53. (Carreg-winllan, Pensarn, S.E. of Amlwch, p. 222.) Exhibits a rather clear base, in which numerous small roundish patches are defined by exceedingly minute opacite and ferrite, the latter sometimes forming the inner edge of the boundary; it is also more or less powdered about through the base. With crossing Nicols this last is seen to be crowded with rather acicular felspar microliths, and the majority of the patches are well-defined spherulites with the usual radial structure. The rock is undoubtedly a trachyte, like the other; and, I think it highly probable that each is from a lava-flow.

Considering the locality and the consequent age of these specimens, their structure is most interesting. So far as my experience goes, there is nothing in either which would have awakened my suspicions as to their age, had they been labelled as from some locality where Tertiary or even more recent trachytes are found.

EXPLANATION OF PLATE VIII.

Fig. 1. Map of Anglesey, showing the distribution of the Palæozoic, Pebidian, and Gneissic series.
2. Generalized section from Holyhead Mountain to Menai Straits.
3. Section across Mynydd Llwydiarth.
4. Section from Porth Nobla to Aberffraw.
5. Section in Upper Quarry, Nebo.
6. Section in Lower Quarry, Nebo.

In all the sections the signification of the letters is as follows :—

d. Carboniferous.
c. Cambrian.
b. Pebidian.
a. Gneissic series:
- a_6. Granitoidite.
- a_5. Dark schist.
- a_4. Grey gneiss.
- a_3. Limestone.
- a_2. Quartz schist.
- a_1. Hälleflinta.

f. Faults.

Discussion.

Dr. Hicks agreed with Dr. Callaway that there are two Precambrian series in Anglesey. He differed from the author, however, in regarding the so-called granitoidite as constituting the lowest and not the highest member of the so-called Gneiss series. He stated that some of the breccias associated with the hälleflintas contain pebbles of the granitoid rocks, and are therefore of younger age than the latter. He admitted, however, that some of the points must be regarded as in an unsettled state, owing to the faulted condition of the district.

Prof. Ramsay argued against the principle of identifying rocks as of different ages by their mineral characters as studied by the microscope. He maintained that the altered rocks of Anglesey are the metamorphosed representatives of the Cambrian, because the unaltered Cambrian are found striking directly towards the altered strata, and both are overlain by the Arenig.

Mr. W. W. Smyth also argued against the recognition of a number of different formations on mineral evidence alone without any aid from organic remains. He thought the so-called "gneissose rocks" differ widely from typical gneisses, and that the granitic series belonged to the class of ill-defined granite rocks known in Cornwall as "bastard granite," the plain Saxon of which was perhaps preferable to the cacophony of "granitoidite." He thought that the evidence brought forward was insufficient to upset the detailed map of the Survey.

Prof. Bonney was inclined to agree with Dr. Callaway's interpre-

tation rather than that of Dr. Hicks, as the latter undervalued the amount of metamorphism the Anglesey rocks by the Menai Straits had undergone. He differed from Prof. Ramsay as to the value to be attached to the microscopic study of rocks; he did not regard the Bangor rocks as partially metamorphosed, and he found no trace of the progressive metamorphism insisted on by Prof. Ramsay. He defended the use of the term "granitoidite," which, though open to objections, was less misleading than the base-born term proposed by Mr. Smyth. He thought that the microscopic study of the rocks supported Dr. Callaway's conclusions.

Dr. Callaway agreed with Prof. Ramsay as to the great value of the Survey work. He contended that the principle of the identification of rocks by their mineral characters is a safe one when applied in the same district. The sections described proved that the granitoidite was the summit of the gneissic series. Many of the gneissose rocks were true gneiss of very typical character. The difficulty through faulting was counteracted by comparing areas.